Improved Environment Support for Modeling and Simulations

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LONG-TERM GOAL

The project long-term goal is to provide a consistent synthetic natural environment that can be used to drive a given scenario in simulation exercises. This project is a joint effort with Scientific Solutions, Inc., and the Advanced Information Technology Branch, Naval Research Laboratory, Washington, D.C., Lockheed Martin, and VisiTech, Inc.

OBJECTIVES

In littoral regions, the properties of the water column are spatially and temporally dynamic. Any realistic simulation of the littoral environment should take into account this variability. During the year under report, our objective was to develop a capability for providing Synthetic Natural Environments to JSAF for two regions, the coastal waters offshore of Camp Pendleton, California during Kernel Blitz '01 (KB-01) and the Persian Gulf during Global '01. Our task also included a sensitivity analysis of the bathymetric requirements for providing realistic ocean simulations.

APPROACH

The ocean environment representation in simulation exercises has to include sea state, water depths, bottom type characteristics, and the three-dimensional structure of the salinity, temperature, and velocity fields. To specify all these ocean parameters as a function of time and space, we utilize numerical wave and ocean circulation models. Such models are prognostic in the strictest sense: the ocean parameters are determined based on energy and mass conservation expressions, typically by solving primitive, non-linear, partial differential equations. Using such models provides an opportunity to be significantly more accurate predictions than statistical relationships. Unfortunately, the predictions are only as good as the accuracy of the energy and mass source and sink terms in the governing equations (e.g., the boundary forcing data) and these models can require considerable computational resources.

To predict the variations in ocean circulation patterns, salinity and temperature, we utilize models that formulate the conservation of momentum, salt, heat, and mass in their most basic forms. For this work, we used a version of the Princeton Ocean Model (POM) called ECOM (Estuarine Coastal Ocean Model). In ECOM, differential equations are used that account for local variations of a parameter, changes due to non-linear advective and turbulent diffusion, pressure effects due to the three-dimensional differences of density (i.e., salinity and temperature), and the temporal and spatial changes in the free surface height (tides, wind-induced setup or setdown, etc.; Blumberg and Mellor, 1987).

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14. ABSTRACT
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ECOM accounts for many sources and sinks in the equation set. These include time-varying river inflows as well as fluxes of momentum, rainfall, and heat fluxes through the air-sea interface. The model forcing functions were gathered from various sources. Sensitivity tests were conducted to understand the range of variations in the simulated oceanographic parameters. To enable access to the data on the oceanographic parameters by the simulation software, an efficient way to transfer data for incorporation in JSAF was developed.

During the current year we have focused on the mine hunting simulation exercise being conducted as part of Kernel Blitz (KB-01) and Global '01. And we also conducted a sensitivity study of the hydrodynamic models to the resolutions of the bathymetric data which were used.

WORK COMPLETED

The approach outlined above was applied to the Catalina Bight off the coast of Camp Pendleton, California and the Persian Gulf and its approaches. Here we describe in brief the work done for these regions.

1. Camp Pendleton, CA

This model was developed in order to perform in-stride computation of ocean environment during the U.S. Naval Exercise KB-01 which was held during March - April, 2001 off the coast of Camp Pendleton, CA. The numerical model has 26 grid cells in offshore direction and 143 cells along shore direction (Figure 1). The horizontal grid spacing varies from about 250 m in the vicinity of Camp Pendleton area to about 2 km offshore. For sea surface elevation forcing data, the Grenoble Ocean Tide Model data are utilized along the boundaries. This tidal model generates the predicted hourly tidal heights for each of the boundary cells. The US Navy, Naval Research Laboratory's Modular Ocean Data Assimilation System (MODAS) (see: www7300.nrlssc.navy.mil/modas/) data archives are used to prescribe time varying temperature and salinity boundary conditions. The MODAS archive provides daily horizontal and vertical temperature and salinity data along the boundary locations.

An automated input processing protocol was used to obtain and process the MODAS data. The data is assimilated for use as input forcing to ECOM by interpolating the MODAS data from its coverage region onto the ECOM boundary. The METOC office in San Diego, CA provided two sets of MODAS data files for temperature and salinity, and the data was provided once per day on most Monday, Wednesday and Fridays. The data was assimilated as soon as it was made available and the model runs updated.

Surface wind stress and air temperature near the sea surface is taken to be spatially constant but varying in time. It is obtained using the US Army Corps of Engineers Coastal Data Information Program (CDIP) [see http://cdip.ucsd.edu/] data (available online). The data is comprised of wind speed and direction as well as air temperature from the Scripps Pier station, and is issued in hourly intervals. The Figure 2 shows the model's ability to predict the surface water temperature. The model results are compared with data obtained during the exercise.
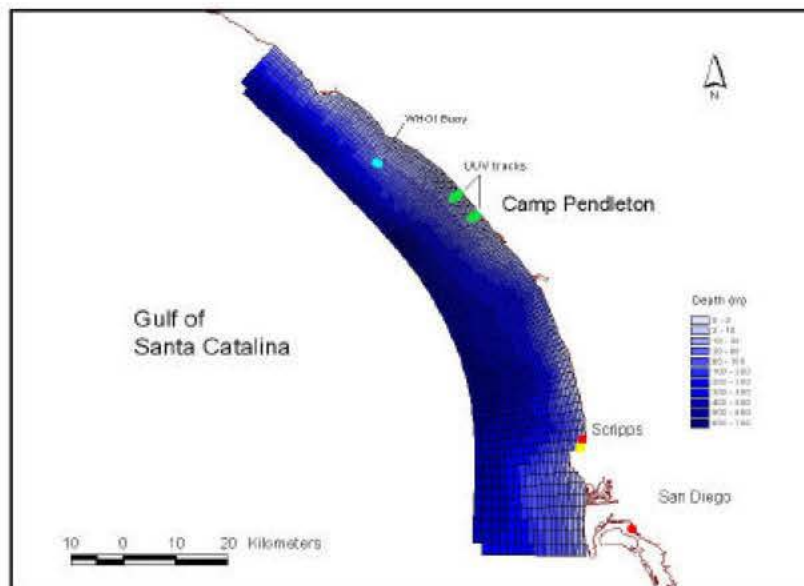
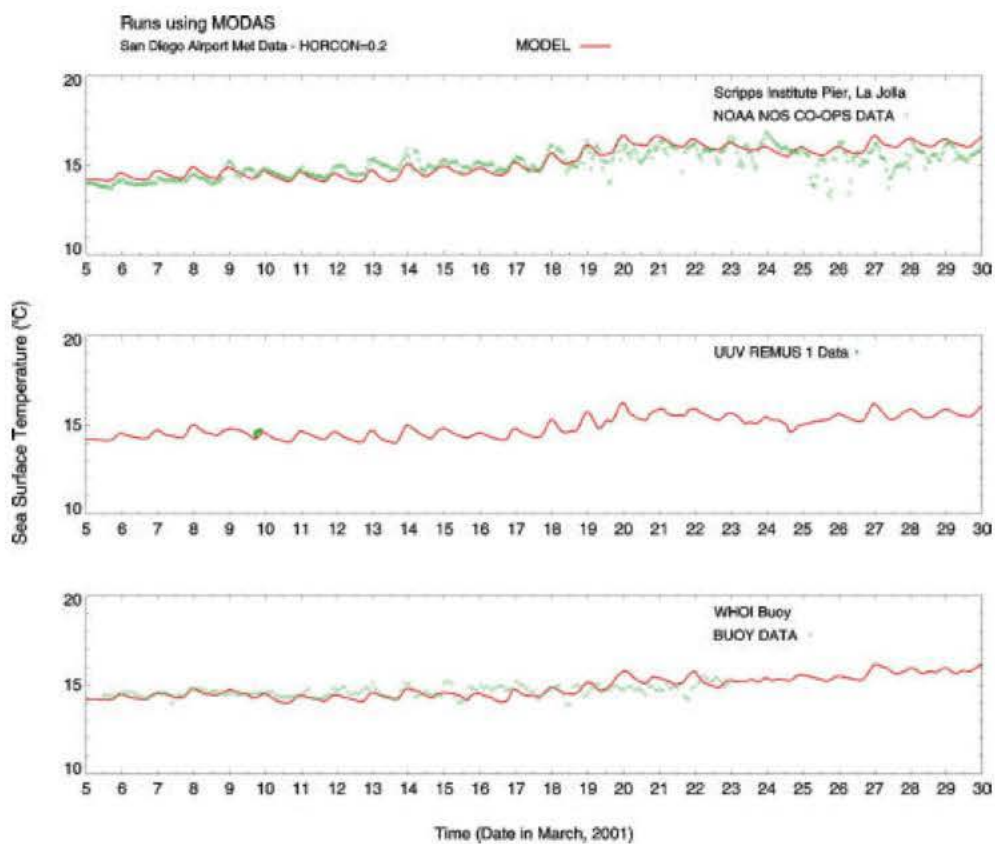*Figure 1. Model grid of Camp Pendleton. Field measurement locations also shown in the figure.*

Figure 2. Comparison of computed sea surface temperature with measured data. NOAA's Scrips Pier, UUV, and Woods Hole Oceanographic buoy are used for comparison

2. Persian Gulf: Global '01

This model was developed to provide an ocean SNE for Global '01 exercises which conducted by Naval War College in July 2001. The objective was to develop a modeling system capable of simulating sea surface elevations, currents, salinity and temperature distributions in the Persian Gulf region. In particular, the goals was: (1) to further refine an existing hydrodynamic model of the region to meet the needs of the Naval War College, (2) to perform some level of calibration/validation of the model using site-specific historical data as well as any more recently acquired data, and (3) to use the model in support of Naval War College requirements.

An orthogonal curvilinear grid system was developed for the Persian Gulf and a part of Gulf of Oman. The grid system has 91 by 20 grid cells in horizontal direction and 11 sigma levels in vertical direction (Figure 3). The model forcing data were extracted from daily MODAS archives for temperature and salinity initial and open water boundary conditions and 12-hourly COAMPS archives for meteorological input. Sea surface elevations were deduced from Grenoble Global Ocean Tidal Model (Le Provost et. el. 1994).

The main deliverable was the production of the ocean environment in the Southwest Asia region during March 2001 conditions. The model output was stored in netCDF format. This includes hourly archives of sea surface elevations, surface wave parameters (significant wave heights, direction of propagation and wave periods), three dimensional current, temperature and salinity fields, turbulent mixing and bottom attributes.
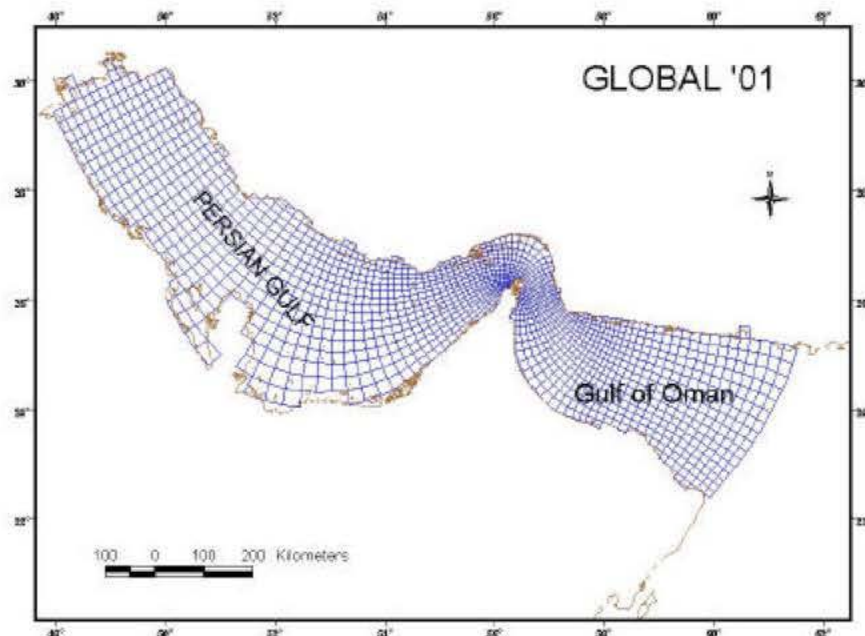

Figure 3. Model grid of Persian Gulf

3. Bathymetric Requirements: A Sensitivity Analysis

Over the past several years there has been a growing realization that bathymetry of the coastal ocean plays a significant role controlling the oceanic processes. Knowledge of the underwater terrain, the bathymetry, is critical and it becomes important to determine in quantitative terms how the accuracy of a bathymetric data set results in system performance errors.

Several different bathymetry resolutions were employed on waters off Camp Lejuene, NC, Panama City, FL and Camp Pendleton, CA. Each of the model depths was configured with the highest resolution data available and then recreated the depths using 2 and 8 km resolutions. The 8 km resolution was chosen as the coarsest resolution because its resolution is close to the resolution of the readily available global topographic database ETOPO5. Of all modeling domains except the Panama City, FL area, 100m high resolution bathymetry data were obtained through NOAA. The Panama City model was configured with 160m resolution bathymetry data. In all, these are bathymetries with three different resolutions for experimentation.

The results of these sensitivity runs of three dimensional hydrodynamic model indicates that changes in the hydrodynamic characteristics in the study area are more noticeable in shallow water area than those in deep waters. Given the response of the hydrodynamic models to different resolutions of bathymetric data, it is suggested that about 500m or less resolution data is necessary for use in coastal ocean modeling. The performance of the sonar system for mine hunting frequency is evaluated using an acoustic model PC-SWAT under three different ocean environment conditions provided by the hydrodynamic model results. The results of the acoustic model also indicate the large errors in the estimate of the system performance under the ocean environments which were generated by using low resolution bathymetry data.

IMPACT/APPLICATIONS

The work presented here provides a means of providing Synthetic Natural Environment that is physics based and consistent with the operational scenario of the sonar system. The SNEs for Camp Pendleton and Persian Gulf were delivered to be implemented in ENVIRO-FED in support of naval exercises.

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